MOPGF034

Development of BPM Readout System Software for SuperKEKB Injector Linac

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SuperKEKB Injector Linac

- **Simultaneous injection for 4 independent rings (SKB e-/e+, PF, and PF-AR) w/ different beam energies.**
- **Increase positron beam intensity:**
  - **1 => 4 nC/bunch**
- **Increase electron beam intensity and Reduce electron beam emittance w/o Damping ring:**
  - **1 nC => 5 nC**
  - **100 mm·mrad => 20 mm·mrad**
- **High precision beam position measurement and control (≤ 10 μm)**

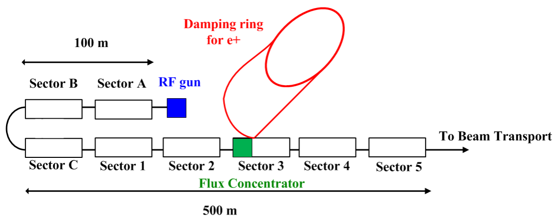


FIG. 1: Schematic drawing of SuperKEKB Linac. Colored parts will be newly installed.

TABLE 1: Main parameters of former KEKB and SuperKEKB.

Parameters	KEKB		SuperKEKB	
	e+	e-	e+	e-
Ring:				
Energy (GeV)	3.5	8	4	7
Stored current (mA)	1.6	1.2	3.6	2.6
Beam lifetime (min.)	150	200	10	10
Injector Linac:				
Bunch charge (nC)*	1 (10)	1	4 (10)	5
Emittance (μmrad)	1400	310	100/20 (Hor./Ver.)	50/20 (Hor./Ver.)
Energy spread (%)	0.125	0.05	0.07	0.08
Bunch length (mm)	2.6	1.3	0.7	1.3

(*) Numbers inside braces denote the charge of primary electron for positron production.

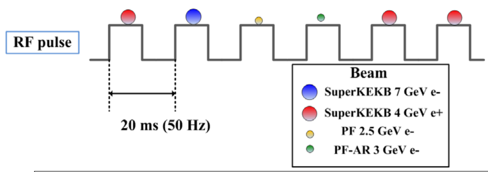


FIG. 2: Schematic drawing of beam operation scheme for SuperKEKB Linac.

Low Emittance Electron Beam Injection (w/o damping ring)

- **Component misalignment (Accelerating structure, Q-Mag.) causes the serious emittance growth.**
- **Simulation was conducted for the 500-m-long straight line (5 nC, initial emittance 10 mm·mrad, Misalignment of accelerating structure: σ =0.5 mm).**
  - **Maximum emittance at end of linac (in 100 different seeds of misalignments) 168 mm·mrad (FIG. 2.)**
- **A precise initial beam offset and angle control can realize the emittance Preservation 11.5 mm·mrad instead of 168 mm·mrad (FIG. 3.).**
- **Precise beam position measurement and control => Crucial issue**

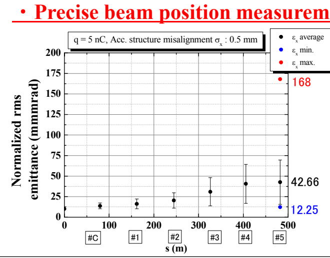


FIG. 3: Simulation result of emittance growth caused by the accelerating structure misalignment.

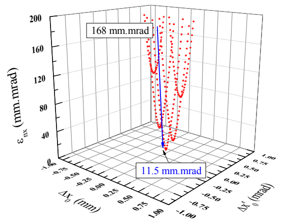
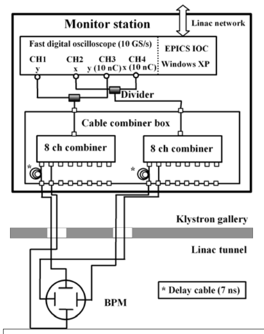


FIG. 4: Simulation result of emittance growth suppression by the fine control of beam orbit.

Current BPM Readout System (Digital Oscilloscope based).



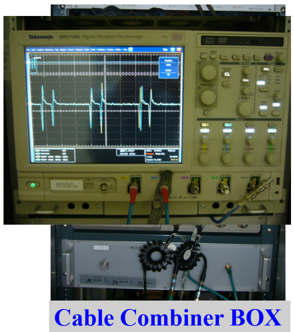


FIG. 5: Schematic drawings of current BPM DAQ system. Twenty four systems process 94 BPMs (WindowsXP-based digital oscilloscope).

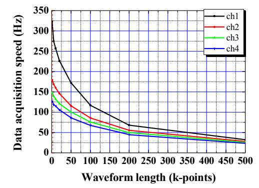


FIG. 6: Data acquisition speed of current DAQ system. For the real beam operation, one oscilloscope processes the waveform of 2000 data points and two channels at the same time up to 50 Hz.

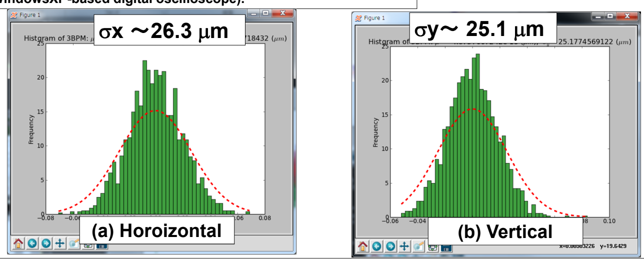


FIG. 7: 3-BPM result of current BPM DAQ system (evaluation of beam position measurement precision).

Outline of New BPM Readout System

- **VME-based module**
- **Based on a band-pass sampling scheme**
  - **Two stage filters**
    - **4th-order Butterworth filter (fc = 180 MHz, BW = 60 MHz)**
    - **2nd-order Bessel filter (fc = 180 MHz, BW = 22 MHz)**
  - **4 channels of 16 bit ADC with 160 MSa/s**
  - **ADC clock: SAW**
  - **ADC input: Passive circuit**
- **Pulse-to-pulse (50 Hz) and two bunch measurement (96 ns interval)**
- **Calibration functionality is available.**
- **EPICS IOC (R3.14.12).**

FIG. 8: Photograph of prototype of BPM readout board (double width VME card).

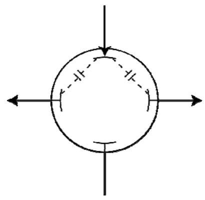


FIG. 9: BPM calibration scheme is illustrated. Calibration tone is provided to the top electrode and induced pulses are generated on both adjacent electrodes with coupling capacitance.

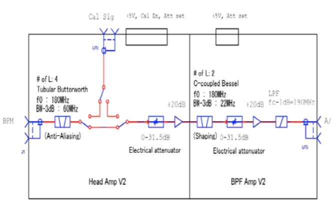


FIG. 10: Block diagram of band pass filter circuit.

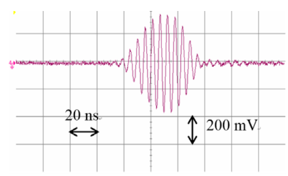


FIG. 11: BPF output waveform.

Summary and Future Plan

- Toward SuperKEKB injector linac upgrade, we have developed a new BPM readout system based on a double width VME card.
- The result of 3-BPM measurement shows a position measurement precision of **σx, y ~ 3 μm**. (Our goal is less than 10 μm)
- Mass production (x108) and installation (x92) have also been completed in this March.
- Calibration and replacement will be finished until end of this year since the beam injection to the SuperKEKB main ring will be started in next February.